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Model-Based Subspace Detectors Constructed with SPECFEM3D

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Waveform correlators enable sensitive detection of weak signals in situations of recurrent seismicity. The empirical approaches being widely studied use well-recorded signals from higher magnitude events as templates to search for signals from much smaller events. Detection thresholds an order of magnitude lower than those achievable with conventional power detectors (STA/LTA on array beams) have been reported with empirically-derived array correlators. However, empirical correlation detectors are, of course, limited to those areas with historical archives of observations and to detecting events with mechanisms consistent with past seismicity.

In this study, we attempt to circumvent these limitations at long periods by constructing waveform correlation-type templates for detection from the best available 3D models using SPECFEM3D GLOBE. We construct waveform basis functions for matching a variety of mechanisms using subspace detectors, a generalization of correlation detectors. Subspace detectors permit a degree of uncertainty about the waveforms being detected by projecting the observed data onto a subspace defined by a collection of basis functions rather than a single template waveform. The basis functions we construct with SPECFEM3D span Greens functions corresponding to the six independent components of the moment tensor.

We examine the potential for detecting aftershocks of the April 2012 Sumatra earthquakes using synthetic templates derived from the S29EA model for stations at regional and near-teleseismic distances. This choice allows us to perform the forward calculation of templates using a single chunk. We build a single multichannel subspace template for several aftershocks and test a subspace detector operating coherently over the observing network. Since our goal is coherent detection over a network, we modify the classical subspace detector (which assumes uniform noise levels on all observing channels) to estimate noise levels on all channels independently while computing the correlation statistic.

We also examine a strategy for ameliorating model error by constructing templates using several models (in addition to S29EA). We expand the dimension of the subspace used by the detector by aligning the waveform templates from a collection of models in a data matrix, then perform a singular value decomposition to obtain a low-rank basis for the synthetics.

Our eventual goal is to cover the aftershock region with a grid of subspace detectors with synthetically-generated templates, pending successful tests of detection of several selected aftershocks. This approach would allow detection and mapping of seismicity throughout the aftershock region. If model-based processing proves to be feasible by producing templates with adequate fidelity to observed waveforms, then the collection of templates could be constructed in a series of reciprocal calculations for each station.

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